Hardwood pallet cant quality and pallet part yields

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Abstract

Raw materials are the largest cost component in pallet manufacturing. The primary raw material used to produce pallet parts are pallet cants. Therefore, pallet cant quality directly impacts pallet part processing and material costs. By knowing the quality of the cants being processed, pallet manufacturers can predict these costs and improve manufacturing efficiency. The purpose of this study was to develop and evaluate hardwood cant grading rules for use by pallet manufacturers and suppliers. Yield studies were necessary to accurately quantify the relationship between pallet part yield and cant quality. Twenty-eight yield studies were conducted throughout the Eastern United States at pallet mills producing parts from hardwood cants. Three preliminary pallet cant grades were used to segregate the cants according to the volume of unsound wood. A total of 47,258 board feet of hardwood cants were graded and processed into pallet parts. Pallet part yield and yield losses were determined for each preliminary cant grade. The average pallet part yield from the preliminary cant Grades 1, 2, and 3 were 83, 77, and 47 percent, respectively. Yield losses attributed to unsound defects were 2, 8, and 39 percent for preliminary Grades 1, 2, and 3, respectively. It was shown that although the grade rules produced statistically different quality divisions between grades, a more practical approach is to establish a single minimum cant quality based on yield and an economic assessment of cant and pallet part value. A new cant grading procedure is proposed specifying a single cant grade permitting up to one-third (33%) unsound volume.

In "price taker" markets, successful firms are the low cost producers, and pallet manufacturers are no exception. The single largest cost component of pallet manufacturing is raw material costs. Cants and lumber typically account for over 60 percent of the operating costs. In the last two decades, cants have replaced lumber as the primary raw material for hardwood pallet manufacturers (Reddy et al. 1997). As stumpage prices and competition for wood-based raw materials increase, pallet cant prices will continue to rise as well. The value of cants to pallet manufacturers is a function of pallet part yield and sawing costs. Knowing the value of cants will help pallet manufacturers more accurately control costs and price products. Even though pallet cants are the largest volume hardwood lumber product produced in the United States, no standard grading rules exists for this product.

The National Hardwood Lumber Association (NHLA) provides grading criteria for Common Timbers and Industrial Blocking that indicate the allowance of unsound wood as long as strength for intended use is not impaired due to this defect (NHLA 2003). However, unsound volume restrictions and size and number of cutting units are not specified.

Several studies over the last 30 years have examined the relationships between hardwood cants and the yield and quality of pallets parts obtained from them (Craft and Whitenack 1982, Craft and Emanuel 1981, Large and Frost 1974, Witt 1972). Most recently, a study by Araman et al. (2003) examined the

percentage of unsound volume in hardwood pallet cants. This research shows that significant proportions – 90 percent – of hardwood cants have less than 10 percent unsound volume, and that only 2 percent of cants have more than 30 percent unsound volume. This study, as well as the others, supports the justification that cant quality can and should be assessed in order to predict pallet part yields and to better control raw material costs.

Research objectives

The objectives of this research were to:

1. determine the relationship between cant quality and the yield of pallet parts,

2. determine how processing systems and saw patterns affect pallet part yield, and

3. develop a practical pallet cant grading procedure.

Materials and methods

Processing data was collected from 28 hardwood pallet mills located throughout the central and eastern United States. **Figure 1** shows the locations of these mills by state. The mills sampled utilized a range of processing equipment. Cant and pallet part characteristics also varied between mills.

Two bundles of approximately 2,000 board feet (BF) of cants were graded at each mill study location. Cant bundles were randomly chosen without regard to appearance. Cants were separated according to three preliminary hardwood pallet cant grades. These grades are described in **Table 1**. While other hardwood cant grade rules have been developed, they were complex and not reflective of part acceptance criteria (Craft and Emanuel 1981, Craft and Whitenack 1982). The grade rules in this study were prepared by White (1989) and represent a three-level partitioning of the range of cant quality observed during previous mill studies. These grade rules were developed based on the allowance of 30 percent or greater unsound wood in cants that roughly accommodate the profitablility of pallet part yields for pallet manufacturers. Subsequently 15 percent unsound cant wood volume increments were used to better understand pallet part yield ratios though the allowable range of unsound cant material.

Hardwood cants were graded by determining both the presence and extent of internal or volumetric defects such as heart rot, decay, wane, insect holes, shake, and splits. The cant grade was based on the percentage of unsound wood volume resulting from these defects. Cants receiving the preliminary grade of Grade 1 or Grade 2 were then further graded by examining the ends of the cants and all four faces. A cant end or face was determined sound if more than 90 percent of its surface area was sound. Final cant grades were assigned according to face grades. Cants were separated and restacked by grade, and the cant volume per grade was calculated and recorded. **Figure 2** shows typical hardwood pallet cants from Grade 1.

Each graded stack of cants was sawn into pallet parts separately. In all of the studies, cants were first cut to part length using a single-blade trim saw. The cants were then ripped into final part thickness. Ripsaws studied during data collection were of two basic machinery classifications: circle gang saws and multiple band saws. For each mill study the type of sawing blade used and its corresponding saw kerf were recorded. Saw kerf was determined by measuring the width of the saw teeth at the cutting edge to the nearest 0.001 inch.

Figure 1. — *Number of study mills sampled in each state.*

Table 1. — *Proposed preliminary grade rules for hardwood cants used in this study.*

Pallet cant grade	Grade description		
	Percent unsound wood	Faces	Ends
1	0 to 15%	3 faces sound 4 faces sound	1 end sound no sound ends
2	16% to 30%	2 faces sound 3 faces sound	1 end sound no sound ends
3	Over 30%		

Notes: Grade decisions should be made using percent unsound rules when internal defects govern cant quality.
Unsound wood includes splits, wane, shake, insect holes, rot, and decay (not drying checks).
A sound face or end contains 90% of the face area in sound wood.

Figure 2. — *Preliminary Grade 1 hardwood cants.*

As cants from each grade were processed separately through the ripsaws, unusable parts were discarded, and the remaining parts were sorted and stacked by size. While each mill discarded parts with serious defects, the criteria by which parts were discarded varied between mills. Parts accepted by saw op-

erators were evaluated for conformance to industry standards (Uniform Standards for Wood Pallets 2003). Parts graded below the "limited use" category and that did not conform to the nailing area requirements in the standards were also rejected. All acceptable parts were tabulated according to part size classifications.

Data analysis

Data analysis began with total yield calculations. The collected data was compiled for each mill study. Yield was calculated according to Equation [1] as the ratio of pallet part volume (PV) to cant volume (CV) less salvage volume (SV). Salvage volume is a cant section removed from the main cant by a crosscut and set aside for processing at a later time. To examine the effect of cant grade on yield, it was necessary to calculate yield separately for each cant grade.

$$\text{Total yield} = (PV)/(CV - SV) \qquad [1]$$

Since salvaged material would be used to produce quality pallet parts of different size, salvage was not considered a loss during yield calculations. Salvage material may still contain defects and was, therefore, subtracted from the raw material volume. All defect losses are related to part yield and not cant salvage material.

Saw kerf and dimension losses are not affected by cant grade. They are a function of processing technique, equipment, and cant and part geometry. Saw kerf and dimension losses were calculated for each mill study as a component of part yield; however, no cant grade based comparisons were necessary. **Figure 3** is a schematic diagram showing typical sawing patterns, parts, salvage, and material losses associated with sawing hardwood cants into pallet parts.

Kerf loss calculations

Kerf loss (KL) is the proportion of kerf volume (KV) to total cant volume (CV). Since cants have variable trim allowances and are always purchased by length to the next lowest foot, kerf loss due to cutting cants to part length is negligible. Crosscut saw kerf was ignored. Equation [2] was used to calculate kerf loss from the mill study data.

$$KL = KV/CV \qquad [2]$$

where:

KV = saw kerf × (number of parts produced per cant section − 1) × cant thickness × part length × number of cant sections and

CV = cant thickness × cant width × cant length.

Dimension loss calculations

Dimension losses (DML) were calculated assuming each cant was processed using the combination of part lengths that resulted in the best possible yield. This calculation ignores defect-related yield losses incurred at the trim saw.

Dimension loss, determined by the cutting bill, relates total part volume (PV), kerf volume (KV), and salvage volume (SV) to cant volume (CV). Some mills ripped cants into multiple
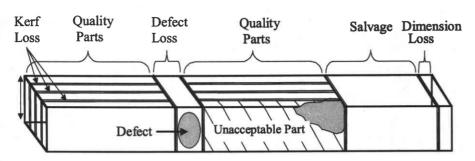

Figure 3. — Schematic diagram showing typical defect losses associated with processing hardwood cants into pallet parts

part thicknesses. While part thickness directly affects dimension loss, part thickness combinations were predetermined and assumed the same for the each production run. Equation [3] was used to calculate dimension loss for the mill data.

$$\text{Dimension loss} = 1 - [(PV + KV + SV)/(CV)] \qquad [3]$$

where:

PV = (part length × number of cant sections) × (total part thickness) × part width,

KV = (kerf × number of saw lines) × part width × (part length × number of cant sections),

SV = (length of cant salvage section) × cant thickness × cant width, and

CV = cant thickness × cant width × cant length.

Defect loss calculations

Defect loss was calculated as a function of total yield, kerf loss, and dimension loss. Defect loss is directly related to cant grade, so it was necessary to determine average defect losses for each pallet cant grade. Equation [4] was used to calculate defect losses from the mill study data for each cant Grade 1, 2, or 3.

$$\text{Defect loss} = \\ 1 - (\text{Total yield} + \text{Dimension loss} + \text{Kerf loss}) \qquad [4]$$

Variation

Considering the variables that affect and determine cant grade – pallet part yield, kerf loss, dimension loss, and defect loss – the degree of variability within these data groups could potentially influence cant grading rules. Therefore, coefficient of variation (COV) was determined for all data groups.

Results and discussion

The data collected at each mill included number of cants, cant volumes, part volume, salvage volumes, and ripsaw kerfs. **Table 2** summarizes the yield study results for the 28 mills studied. In all, 2,016 hardwood cants totaling 47,258 BF were graded during these studies. The total volume of pallet parts and salvage material produced were 36,462 and 1,754 BF, respectively. **Table 3** contains the range of pallet cant and part sizes from the pallet mill studies. The ranges represent the typical cant and part sizes sawn by the pallet industry. **Table 4** provides a summary of pallet part yields as a function of cant grade, defect loss, dimension loss, and kerf loss. Average total

Table 2. — Summary of cants, pallet part yields, and salvage material from hardwood cants processed at 28 cooperating pallet mills.

28 mills	No. of cants				Cant volume (BF)				Part volume (BF)				Salvage volume (BF)			
	Preliminary cant grade				Preliminary cant grade				Preliminary cant grade				Preliminary cant grade			
	1	2	3	Total	1	2	3	Total	1	2	3	Total	1	2	4	Total
Total (%)	1,409 70%	388 19%	219 11%	2,016	33,207 70%	8,991 19%	5,063 11%	47,258	27,113 74%	6,881 19%	2,459 7%	36,462	1,379 79%	244 14%	131 7%	1,754
Avg. per mill	50	14	8	72	1,186	321	181	1,688	968	246	88	1,302	49	9	5	63
COV[a]	50%	70%	103%	40%	63%	82%	108%	47%	66%	84%	122%	52%	237%	176%	237%	206%

[a] COV = coefficient of variation (standard deviation / mean)

part yield was 78 percent for all mills studied, and cant Grades 1, 2, and 3 yielded an average of 83, 77, and 47 percent part volumes, respectively. Part yield COV was 9, 11, and 21 percent for Grades 1, 2, and 3, respectfully. Not surprisingly, yield COV for Grade 3 cants was relatively large since Grade 3 simply represents all levels of unsound wood greater than 30 percent.

Hardwood cant quality distribution

The relative number of cants per grade indicates the quality distribution of cants used by the mills studied. **Table 2** contains the total volume of each cant grade sawn at the study pallet mills. Of the 2,016 cants graded in the study, 70 percent (1,409 cants) were Grade 1, 19 percent (388 cants) were Grade 2, and 11 percent (219 cants) were Grade 3.

The high percentage of Grade 1 cants by volume supports the basis that the pallet industry is sawing a high percentage of sound cants. Nevertheless, the results of this study are only applicable within the parameter ranges of the pallet mills sampled. Market forces may result in changes in these distributions.

Yield losses from sawing hardwood cants into pallet parts

Three yield loss components were calculated: defect loss, dimension loss, and kerf loss. From **Table 4**, average yield loss by component for all cants processed were as follows: 10 percent kerf loss, 7 percent defect loss, and 5 percent dimension loss.

Defect loss was determined for each cant grade. Kerf and dimension losses are a function of the cutting bill, ripsaw blade orientation, equipment, and pallet part and cant geometry. They are not affected by cant grade and were, therefore, determined for all cants as a whole. Pallet part yield is a combination of both pallet stringers and deckboards. Average defect losses were 2, 8, and 39 percent for cant Grades 1, 2, and 3, respectively. Defect loss COV for Grades 1, 2, and 3 were 76, 34, and 28 percent, respectively. Although COV was larger for Grades 1 and 2, the low mean values reflect relatively small standard deviations and are consistent with accuracy in the grading rules.

Table 3. — Range of pallet cant and part sizes from pallet mill studies.

	Cant			Pallet part		
	Thickness	Width	Length	Thickness	Width	Length
	------------------------------ (in) ------------------------------					
Lowest	3.00	4.00	96.00	0.44	3.00	31.75
Highest	7.25	8.00	196.00	1.88	6.00	72.00

Table 4. — Average pallet part yields and yield losses from all 28 pallet mill studies.

	Pallet part yield				Defect loss				Dimension loss	Kerf loss
	Preliminary cant grade				Preliminary cant grade					
	1	2	3	Total	1	2	3	Total		
Avg. (%)	83	77	47	78	2	8	39	7	5	10
COV (%)	9	11	21	12	76	34	28	58	102	56

A Tukey Studentized Range Test indicated defect losses were significantly different between all of the grades. Defect losses were expected to be consistent with the percentage of unsound material by grade according to the proposed hardwood cant grading rules. The significantly low defect losses for Grades 1 and 2 were due to high-quality cants with low volumes of unsound material.

In this study, dimension losses in pallet mills producing multiple size parts were nearly 2 percent lower than mill producing only single size parts. Mills salvaging short cant sections reduced dimension losses by 0.8 percent compared to mills not salvaging cant sections.

Effects of ripsaw selection on pallet part yields

Ripsaw kerf ranged from 0.036 to 0.188 inch with the average of 0.109 inch. Ripsaw kerfs were compared with circle gang saws and multiple bandsaws. The average saw kerf thickness for multiple bandsaws and circle gang saws were 0.056 and 0.138 inch, respectively. Thicker saw kerfs resulted in higher kerf losses and lower yields, which implies higher part costs. The average kerf loss from multiple bandsaws and circle gang saws was 6 and 13 percent, respectively. This difference in kerf loss reveals that a 7-percent increase in yield can be attained through the use of thin kerf multiple band saws.

The large variation in kerf loss within each saw kerf class is attributed to differences in sawing patterns associated with production of different pallet part sizes. However, statistical analysis indicated that a significant correlation exists between saw kerf size and yield loss due to kerf.

Evaluation of hardwood cant grading rules

Determining the magnitude of internal defects in a cant was subjective, but a good approximation was possible by examining both ends and all four sides. The grading process was quick because cants with unsound volume greater than 30 percent were assigned a final Grade 3 without requiring the application of face grading rules. Determining the total volume of unsound material often allowed the grader the ability to forgo further examination of the sides and ends.

One problem with the grading criteria used in this study was the caveat that a Grade 1 cant must have at least four faces that contain 90 percent of more of the surface area in sound wood. A cant containing wane (usually from small-diameter logs) but an otherwise low volume of unsound wood (less than 15%) could be initially classified as a Grade 1 cant. However, the strict "90 percent sound wood face" grading criteria downgraded some Grade 1 cants with low percentages of unsound wood to a Grade 2. Grade 2 cants often contained high percentages of sound material. Resulting defect losses were lower than the expected 15 to 30 percent for this grade.

The proposed face grading criteria was not accurate. The fact that average defect loss was lower than expected indicates the high percentage of sound wood volume in hardwood cants. Low defect losses, high average pallet part yield, and little variation within these two data groups support the adoption of a singe cant grading rule.

Current market prices for hardwood cants and pallet parts indicate that a minimum pallet part yield of roughly two-thirds is required for a typical pallet manufacturer to break even economically (Pallet Profile 2005). Consequently, this indicates a maximum allowable yield loss of 33 percent. Since this research shows that average kerf and dimension losses combine for 15 percent of total yield loss when processing hardwood cants into pallet parts, it appears that unsound defect losses in excess of 18 percent would cause cants to become unprofitable for pallet part production. However, it is important to note that some unsound wood volume will be included in kerf and dimension losses during cant processing. It is also true that, depending on the grade of the part, significant amounts of unsound wood are permitted in pallet parts (Uniform Standards for Wood Pallets 2003). Other restrictions include no decay in stringer notch areas and no wane or decay on the outer edge of endboards, or on the exposed sides of stringers or blocks (Uniform Standards for Wood Pallets 2003) .

Based on a break-even yield loss maximum of approximately 33 percent – which includes the 15 percent for kerf and dimension loss unrelated to cant quality or grade – it is reasonable to allow an additional 15 to 18 percent unsound wood volume to be present in cants to compensate for unsound wood lost in kerf and dimension losses and unsound wood permitted in pallet parts.

It is recommended that the hardwood cant grading rules used in this study be simplified into a single practical grade rule based entirely on a maximum allowable unsound wood volume of one-third total cant volume (33%).

Recommendation for new hardwood cant grade rules

Hardwood cants range from 4 by 6 inches to 8 by 8 inches in width and thickness and 8 feet and longer in length. In contrast to general lumber or boards, a cant has four distinct faces and two ends that require inspection when an attempt is made to determine its overall quality. In the case of hardwood cants for pallet parts, quality is determined by the percentage of sound wood volume in a cant from which pallet parts can be manufactured at a profit. From this research, it has been determined that a cant should have at least two-thirds sound wood volume. Unsound wood present in the form of heart rot, decay, insect holes, splits, shake, and wane reduce cant quality and compromise the yield of pallet parts that can be obtained. Sound knots, however, are perfectly acceptable.

Because of the three-dimensional similarities between a cant and a log, a simple cant grading technique is proposed that draws on log grading criteria used by the *Forest Service Standard Grades for Hardwood Factory Lumber Logs* (Rast et al. 1973). Hardwood cants come from the center of a log and are not significantly affected by sweep or crook that may be present in a log. No considerations for these defects are necessary. Since it has been shown that a reasonable economic indicator for allowable unsound wood in a cant is roughly 33 percent, the proposed hardwood cant grading rule allows up to, and including, one-third of the volume in a cant to consist of unsound wood. The following is a proposed grading procedure for hardwood pallet cants:

1. Observe and evaluate all four cant surfaces for volume-reducing defects such as heart rot, decay, insect holes, splits, shake, and wane.

2. Based on the area of unsound wood defects, select the second from the worst face. This then is the grade face.

3. Evaluating the grade face, determine the percentage of unsound wood (GFD) as a ratio of the surface area of the unsound defects on the face (SAD) to the surface area of the face itself (SAF).

   Grade face volume deduction (GFD) = SAD (in^2) / SAF (in^2)

4. Check for unsound end defects. Estimate interior unsound wood volume deductions present at the ends of the cant (CED) using the methods for interior deductions described in the *Forest Service Standard Grades for Hardwood Factory Lumber Logs* (Rast 1973). If unsound wood visible on the end of a cant is adjacent to, or the same as, unsound wood observed on that end of the grade face, ignore the unsound defect in the grade face.

5. Add the grade face (GFD) and the percent of cant end (CED) volume deductions to determine the percent of total unsound wood volume present in the cant.

   Total unsound wood deduction = GFD + CED

6. Cants with unsound wood volume in excess of 33 percent (one-third) are below grade, and therefore, cull material.

Conclusions

- Cant quality significantly affects pallet part yields. Preliminary cant Grades 1, 2, and 3 used in this study resulted in average pallet part yields of 83, 77, and 47 percent, respectively.

- The preliminary hardwood cant grades resulted in average defect losses of 2, 8, and 39 percent for Grades 1, 2, and 3, respectively.

- The pallet industry is using a relatively large percentage of sound cants. Preliminary cant Grades 1 and 2 (cants

with less than 30% unsound wood volume) represented 89 percent of the cants and cant volume in this study.

- Kerf loss is the largest yield loss component from processing pallet cants into parts. In this study, kerf loss was 10 percent, followed by defect and dimension losses at 7 and 5 percent, respectively.

- Pallet part yields are 7 percent higher when thin-kerf band saws are used instead of circle gang ripsaws.

- Cutting multiple length parts resulted in a 2 percent higher yield compared to single length part production from cants. Salvaging short material increased part yield nearly 1 percent.

- A new hardwood pallet cant grading procedure was proposed based on the *Forest Service Standard Grades for Hardwood Factory Lumber Logs*. In this new procedure, unsound wood volume is tallied from both a specified grade face and the cant ends. When combined, unsound wood volume is limited to a maximum of one-third the surface area of the grade face and the unsound wood in the ends of the cant.

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